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INTAKE AND URINARY EXCRETION OF SODIUM CHLORIDE UNDER VARYING CONDITIONS OF EFFORT AND ENVIRONMENT HEAT

by

Ezra Zohar, Raphael Adar, Jacob Tennenbaum and Moshe Kesten

Translation of Harefuah, Journal of the Medical Association of Israel, Vol. 60, No. 10, 15 May 1961, pp. 326-332.

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16. Abstract

Intake and urinary excretion of sodium were investigated in a group of young, healthy and acclimated men during a trip from Eilat to Metullah in the month of August 1959 and in a group of naturopaths living near Safed in August 1960. Also investigated were the sodium excretions of workers in Eilat and of machinists in the engine rooms of a ship.

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INTAKE AND URINARY EXCRETION OF SODIUM CHLORIDE UNDER VARYING CONDITIONS OF EFFORT AND ENVIRONMENT HEAT[1]

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Introduction

Since table salt is the most important component, quantitatively, in human perspiration, it has been assumed that under conditions of excessive perspiration a salt deficiency may develop in the body. It has been proven, however, that within hours of the occurrence of excessive perspiration, a passing surplus and not a deficiency of table salt will be generated (because of the perspiration being hypotonic to plasma [24]). There was still the opinion advanced that continued exposure to conditions of heat and effort would cause a deficiency of salt in the body fluids. The purpose of this study has been to clear up that question and to establish whether the danger of salt deficiency exists, under the conditions prevailing in our country in the summertime, for healthy, acclimated males working in hot environments and eating a normal diet.

On the face of it, the simplest way to investigate that point is the direct measurement of salt amounts in the perspiration. It is known, however, that the salt concentration in perspiration varies greatly with intensity and duration of the perspiration, the season of the year, the parts of the body involved, climatic conditions, etc. [14]. Moreover, the known methods for examination of sweat samples from solution contents are so inaccurate that differences of up to 2000% are found between the various estimates cited in the literature [3, 13, 24, 29]. Reliance on such sweat samples brought one group of authors even to estimate the loss of table salt in perspiration at 30-40 g per day! [16]. The method of collecting all the body perspiration is not realistic for a period of a few hours.

Our approach to the problem is based on the body's calibration

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*Numbers in the margin indicate pagination in the foreign text.

[1]This work was partially supported by the Ford Foundation F-3 grant and partially by the Medical Corps of the Israel Defense Forces (IDF).

system for maintaining the salt balance in the bloodstream. A healthy person excretes only excess amounts of sodium and chlorine in the urine. In cases where the salt intake does not meet the needs of the body (in this case because of the loss of sodium chloride through perspiration), the amount of sodium and chlorine in the urine will decrease and, finally, reach zero [5, 19]. It is clear that the disappearance of sodium chloride from the urine will precede the decrease of those ions in the blood, while, on the other hand, the presence of sodium and chlorine in the urine is a sure sign that there is no deficiency in those ions.

Materials and Methods

The observations were carried out with a group of 19 young men in good physical condition, who marched with a pack of 15 kg on their backs from Eilat to Metullah between 3.8.59-26.8.59. They averaged 27 km daily in 6 hours and 20 minutes (including 3-4 rest periods). The marching hours were between 07:00-13:30. On Saturdays (8.8.59, 15.8.59, 22.8.59) the men rested. For the purposes of the test, numbers 1-19 were assigned to the men. During the trip four different menus were tried out. The intake of food and salt (which we did not restrict) was carefully monitored for ten of the men. Every marcher received a personal saltshaker, which was weighed before and after each meal. The amount of salt in the meal was determined through: 1) weighing the salt put into the food during cooking; 2) weighing of each food portion eaten by one of the marchers; 3) use of existing tables [32] for standard food items and 4) laboratory analysis of sodium and chlorine content in other food items and in all beverages consumed, including water.

The urine of the ten men (1-10) was collected in closed containers which had previously been rinsed twice in distilled water. The amount of urine was recorded and samples of each urine were tested in the laboratory of Tel-Hashomer Hospital to determine the sodium and chlorine concentrations present. The creatinine content of the urine for 24 hours was measured to ascertain the integrity of the collected samples.

Under normal conditions, the sodium contained in the feces represents at the most 3% of the total daily sodium excretion [20],

so this source of sodium loss could be neglected.

Several times blood samples were taken in the morning, on an empty stomach, to determine the level of electrolytes in the blood serum. The blood was put into a centrifuge on the spot and the serum was sent in sealed containers, which had previously been rinsed in distilled water and dried, to be examined in the laboratory.

Since it is easier to express the salt intake in grams, the quantities of salt found in the urine and in the blood will be expressed in milligrams and not, as customary, in milliequivalents. Sodium makes up 40% of table salt, by weight. One gram of sodium is found in 2.5 g of table salt.

The sodium level in blood serum and in urine was measured in the laboratory with a flame photometer [11]. The level considered normal at that laboratory, at the time, was 290-335 mg%. The chloride level was determined according to the method by Schales & Schales [25], the values considered as standard being between 345-385 mg%.

An additional record was kept of the various meteorological conditions, which made possible an estimate of the heat at each of the trip's stages by using the cumulative discomfort index method (Cum D.I.) [28]. Daily amounts of perspiration were determined by means of accurate scales for fluids and by repeated weighings [28].

During a continuation of the investigation in the summer of 1960, three groups of people, who demonstrated various combinations of effort, heat stress and sodium intake, were tested with the same methods.

The tests were arranged in the following manner:

a) collection of urine from workers in factories and in the harbor of Eilat, who do heavy physical labor under conditions of extreme heat;

b) collection of urine from machinists working below deck on ships, who are working in a very hot environment - more so than what may be expected under normal conditions - but do not do hard work;

c) accurate sodium balances among members of a village of naturopaths, Amirim, who exert little physical effort in the summertime and whose sodium intake is very low.

Results

1. On the Trip from Eilat to Metullah

a) General sodium intake: In the course of 24 days, each of the ten men consumed an average of 6.08 g sodium (corresponding to 15.2 table salt) daily. The average for the three Saturdays was 5.44 g sodium. The intake varied over a broad range; the minimum was 2.64 g sodium on a Saturday and 2.96 g sodium on a marching day, while the maximum was 11.14 g sodium per day. The individual average for each man during the 24 days of the trip varied from 4.19 g sodium (subject 10) to 7.17 g (subject 7) (see Table 1).

Overall sodium intake came from three sources: 1) food, 2) beverages, 3) salt that was added to meals according to taste. A survey of the individual food records showed that 82.9% of the sodium came from the food. This value changed from day to day and from man to man, depending on the menu and the quantity of food. The part of sodium that was derived from drinking water and other beverages averaged 12.4% of the daily intake. On Saturdays that average was lower, because of decreased drinking. Drinking water, which was taken from various sources along the trip, contained 52.1-187.7 mg sodium/liter.[2] Daily consumption on marching days averaged from 6.9-10.5l/person (see Table 2). That amount of water intake supplied about 0.5-1.5 g of sodium daily to each man. The part of sodium that came from voluntary addition of salt to the food averaged 4.7% of the general sodium intake [1].

b) Urinary sodium excretion: Daily urinary sodium excretion was measured on 14 out of 24 days of the trip, for subjects 1-10. An analysis of the creatinine values in the urine proved the integrity of the urine collections.

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[2] We are indebted to the laboratories of the Mekorot Co. for making these tests.

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Table 1

Overall intake of sodium in grams during a 24-hr cycle on the trip from Eilat - Metullah (subjects 1-10)

Date	1	2	3	4	5	6	7	8	9	10	Daily average
3	4.11	5.73	6.72	3.73	5.29	6.31	8.09	5.96	5.05	4.48	5.69
4	5.43	7.19	6.64	6.51	5.54	6.41	8.64	5.98	7.26	5.34	6.49
5	6.21	8.75	3.17	6.23	6.68	8.10	9.74	7.11	8.79	5.65	7.44
6	6.89	8.18	4.2	6.73	5.41	5.44	9.33	5.39	6.54	5.01	6.57
7	7.25	7.17	7.89	5.46	5.00	6.72	8.36	8.49	8.36	4.79	6.87
Sat. 8	6.10	8.47	5.62	5.91	4.98	6.06	7.51	8.43	7.28	4.98	6.65
9	7.78	9.70	6.83	4.98	3.18	7.04	8.74	7.62	6.79	4.43	6.70
10	6.12	8.40	7.28	6.83	5.59	6.04	8.57	6.16	6.29	6.28	6.75
11	8.16	8.82	7.62	7.53	6.99	2.95	5.91	7.79	6.51	4.53	6.68
12	8.56	11.14	6.86	7.90	6.98	6.96	8.49	8.16	6.81	4.74	7.53
13	6.07	6.62	7.07	6.49	5.16	7.24	6.69	8.24	6.93	4.62	6.51
14	6.85	7.30	6.32	6.95	4.72	5.45	8.24	7.89	6.21	5.85	6.48
Sat. 15	4.45	4.65	5.68	5.52	4.63	5.03	5.78	6.70	5.89	No record	5.37
16	5.12	6.85	5.74	5.62	3.48	4.01	5.52	5.82	5.21	5.31	5.27
17	4.57	6.51	6.50	3.69	3.50	3.58	4.88	5.16	5.79	5.37	4.97
18	6.40	7.71	7.09	6.64	4.79	6.63	5.12	6.67	6.02	4.33	6.14
19	5.42	5.60	5.58	5.02	3.66	3.94	7.15	6.65	3.65	4.51	5.12
20	6.74	6.17	7.04	4.53	6.94	4.75	5.65	8.15	4.98	5.26	5.96
21	6.46	4.71	6.75	7.27	6.72	6.85	7.23	8.20	7.48	6.08	6.77
Sat. 22	5.38	4.84	4.77	4.75	2.96	2.63	4.38	6.34	5.56	3.43	4.50
23	4.15	4.48	5.98	4.98	5.13	5.41	3.83	9.23	5.45	4.67	5.33
24	4.99	4.38	6.37	5.37	5.21	4.09	8.22	6.15	3.91	5.30	5.40
25	5.63	4.44	6.91	6.10	3.77	3.63	7.97	6.24	3.22	4.41	5.23
26	6.59	5.71	5.81	5.17	4.81	5.89	8.13	6.06	6.29	4.23	5.88
Individual Average	6.07	6.81	6.41	5.83	5.01	5.44	7.17	7.02	6.16	4.91	6.08

Table 2

Average quantities of liquid input (liters/24-hr.) for 19 marchers in 24 days.

Date	Quantity of Drink	Date	Quantity of Drink
3	10.12	Sat. 15	6.89
4	10.46	16	7.76
5	8.78	17	7.86
6	8.45	18	7.60
7	9.71	19	6.92
Sat. 8	5.76	20	8.18
9	7.00	21	7.38
10	7.04	Sat. 22	4.47
11	7.69	23	8.22
12	8.11	24	10.00
13	8.39	25	8.76
14	8.31	26	8.93

Daily urinary sodium extraction varied over a wide range but only in 13 out of the 139 measurements was an amount of less than 1 g of sodium daily found. Four of the low measurements were made on 8.24, when the general average for the ten men was the lowest of all daily averages: 1.1 g sodium. One of the marchers (subject 1) almost reached zero excretion that day, 0.01 g sodium in a 24-hr. period. The general average of daily excretion was 4.06 g sodium (corresponding to 10.15 g table salt) during 24 hours. The highest daily average for the ten men was 7.24 g sodium daily. Individual averages for 14 days, during which urinary excretion was measured, varied from a minimum of 1.91 g sodium daily for subject 1 to a maximum of 5.59 g for subject 8 (see Table 3).

c) Levels of sodium and chlorine in the blood serum: Several times during the trip, blood samples were taken in the morning on an empty stomach to determine the levels of sodium and chlorine in the blood serum. All of the values were found to be within normal limits, and no tendency was seen for a decrease or any other tendentious change in the level of electrolytes in the blood serum at the end of the trip.

Twice during the trip the sodium level in the blood serum of subjects 15-19 was measured, on getting up in the morning and immediately after conclusion of the daily effort. On 8.5.59, there was no limitation of drinking and blood samples taken at the end of the march, before the men had a chance to quench their thirst generated by the last stage of the march only. On 8.17.59, drinking was limited during all stages of the day's march to only 900 ml of water Immediately after conclusion of the march, blood samples were taken and only afterward could the men quench their thirst. The results of that test are shown in Table 4.

While on 8.5.59 there was an average difference of 2% mg of the sodium values in blood serum, between start and finish of the effort, on 8.17.59 there was an average increase of 31% mg of those values at the end of the marching period (minimum increase was 17% mg and maximum - 62% mg). The chlorine values of this test also showed similar tendencies. On 8.5.59, the average difference between start

and end of the effort was 7% mg, while on 8.17.59, the average increase was 30% mg (minimum - 21% mg and maximum - 40% mg).

On a day when drinking was not limited, the men drank an average of more than 3 liters during the march; when drinking was limited, they drank less than 1 liter. This was expressed by the degree to which the men were dehydrated: on 8.5.59, the men finished their march with an average dehydration of 2.3 kg, while the dehydration average on 8.17.59 was 3.8 kg (see Table 5). It is well to point out that the heat stress during marching hours was heavier on 8.5.59 than on 8.17.59.

d) Heat stress and quantities of perspiration. In Table 6 are shown the values for the cumulative discomfort index (cum D.I.) for each of the days of the march and the average values for the daily quantities of perspiration. On the effort days, the men perspired an average of 5.5-10.3 liters and on Saturdays, between 2.5-4.8 liters during 24 hours.

e) Clinical observations. All the marchers were under clinical observations by a team of four physicians, 24 hours a day. During this entire period the men were in good shape, both physically and with respect to morale. Not once during the trip did anything occur that could be explained as pathological phenomenon caused by salt deficiency.

f) Differences due to origin (of the marchers). Four of the marchers were Ashkenazis (of European origin) (subjects 1, 2, 7 and 9), the rest were of other origins. No difference of any significance were found between the two groups in their salt intake, its excretion, or in the sodium and chlorine levels of their blood.

2. Urine Collection Among Workers at Eilat

The participants in this test were 20 workers in a factory for the pouring of concrete plates who were working under coverings that protected them from direct sunlight and from wind in two directions, as well as 15 harbor workers who worked in open space without any protection. The two locations were similar as to heat stress conditions and the variations were small, so we did not differentiate between the two groups. The average cumulative discomfort index

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Table 3

Urinary sodium excretion in grams for a 24-hr period during the trip from Eilat to Metullah, for subjects 1-10.

Date		1	2	3	4	5	6	7	8	9	10	Daily Average
	3	0.84	6.10	4.38	1.44	0.93	2.80	1.61	2.35	3.66	1.84	2.72
	4	0.59	8.94	9.90	0.44	2.39	5.53	0.98	3.27	3.33	1.25	3.67
	5	0.57	16.29	7.75	1.08	1.60	9.90	0.75	10.84	11.14	2.51	7.24
	7	5.00	5.55	7.98	8.23	1.30	3.40	8.01	14.65	9.88	5.32	6.93
	10	3.65	7.90	5.02	3.42	4.86	6.50	4.71	5.88	7.88	5.52	5.39
	12	1.88	5.72	4.92	3.02	2.47	1.65	2.64	4.28	5.89	0.81	3.39
	14	1.07	3.04	6.17	3.40	1.74	2.70	2.89	4.68	3.96	1.85	3.16
Sat.	15	2.93	3.62	8.15	3.64	0.16	1.56	4.53	2.44	3.45	No Record	3.38
	17	2.37	7.04	5.28	3.52	2.27	5.32	5.31	5.16	6.42	6.88	4.87
	18	2.67	6.97	4.83	3.63	2.25	3.25	4.41	7.83	5.60	4.32	4.67
	20	1.40	2.68	2.57	2.41	2.43	4.11	6.72	5.42	3.10	4.49	3.53
Sat.	22	2.46	2.80	3.55	4.00	3.90	2.87	3.61	5.93	4.43	2.98	3.65
	24	0.01	1.41	2.41	0.68	0.78	0.73	1.38	1.44	1.05	1.35	1.10
	26	0.86	4.16	6.04	1.60	1.82	4.11	4.93	3.91	3.83	1.98	3.14
Individual Average		1.91	5.87	5.62	3.03	2.06	3.83	4.33	5.39	5.34	3.05	4.06

Table 4

Level of sodium and chlorine in the blood serum (in % milligram) at the start and finish of the effort on a day of unlimited drinking (8.5.59) and on a day of limited drinking (8.17.59), on the trip from Eilat to Metullah.

Subject Number	8.5 - Unlimited Drinking				17.8 - Limited Drinking			
	Sodium		Chlorine		Sodium		Chlorine	
	Start	End	Start	End	Start	End	Start	End
15	282	284	361	367	284	314	338	338
16	288	282	348	361	288	320	349	376
17	278	288	348	361	288	324	349	381
18	292	284	355	349	288	330	335	365
19	282	282	349	358	288	314	335	376
Average	284	286	352	359	288	324	338	359

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Table 5

Comparison of fluid intake quantity (in liters) and dehydration (in kg of body weight) during marching days 8.5.59-8.17.59.

Subject Number	8.5.59 Input	8.17.59 Input
15	3.30	0.90
16	2.89	0.90
17	3.50	0.90
18	3.79	0.90
19	2.10	0.90
Average Liquid Input	3.12	0.90
Average Dehydration	2.32	3.83

Table 6

Average quantity of perspiration (subjects 1-10) in liters for a 24-hr. period during 24 days of marching, and discomfort index values.

Date	Perspiration Quantity	Cum. D.I.	Date	Perspiration Quantity	Cum. D.I.
8.5.	10.80	24.0	8.15.	4.70	49.8
8.6.	8.41	49.0	8.16.	5.95	20.8
8.7	7.24	28.1	8.17.	6.19	28.1
8.8.	7.26	28.6	8.18.	6.88	26.1
8.9	8.91	30.0	8.19.	6.64	19.0
8.10.	4.57	25.9	8.20.	5.63	18.2
8.11.	5.68	6.4	8.21.	6.67	15.3
8.12	5.67	15.5	8.22.	2.45	14.7
8.13.	7.51	13.3	8.23.	7.72	37.0
8.14	5.49	16.7	8.24.	8.86	64.8
8.15.	7.56	27.6	8.25.	7.87	45.2
8.16.	7.23	26.0	8.26.	7.68	25.8

for working hours was 24.6. This situation represents a normal summer day in Eilat.

All men were fed a regular diet (without any influence or explanations from us). One man (subject 8) used to take a number of salt tablets (up to 10 tablets a day) - on advice from his physician, which contained 0.5 g table salt per tablet.

In Table 7 are shown the average values for each subject, for urinary sodium excretion during a 24-hr period, from 58 collections that were taken from 24 men. The average excretion was 3.2 g sodium (corresponding to 8.0 g table salt) daily. The minimum was 0.16 g sodium daily (subject 15) while the maximum (subject 8 who took additional salt tablets) was 10.27 g sodium daily. Only three men averaged less than 1.0 g sodium daily. None of the workers developed any kind of clinical problems whatsoever.

A few urine collections were also made during working hours - 70 collections among 31 workers. Differences between the values from working hours and those of the daily average were slight and without significance. During working hours the men excreted smaller amounts of urine per hour than the average per day (33 ml against 39 ml) and the salt concentration was slightly higher (3.64 g/l against 3.34 g/l).

Comparison between the cumulative discomfort index values during the periods of effort on each day of the test and the average values for urinary excretion and sodium excretion in the urine during those periods (see Table 8), shows that the differences between the data (urine and sodium) for different days are not significant and that there is no parallel between changes in those values and changes in the cumulative discomfort index.

3. Urine Collection Among Machinists Working in Ships' Engine Rooms

During a test which lasted 40 hours (from 04.00 on 7.6.60 to 20.00 on 7.7.60), 9 machinists participated, each of whom worked 4 hour watches. The men were assigned numbers 1-9, the watches received designations A-K.

The stress of heat in the engine rooms and outside them is expressed as the cumulative discomfort index for the four hours of each watch. Conditions inside the engine rooms were such that the average heat stress was 4 times (!) greater inside than outside. The cumulative discomfort index (cum D.I.) average for 4 hours: inside the engine rooms 37.8, outside them 9.3.

Subjects 1 and 2 worked 4 watches during the test period, the others worked only 3 watches. The work itself was relatively easy,

in fact the men only had to see that the machines were performing normally.

All machinists were fed a regular diet and did not change their eating habits during the test. Excretion of urine and of the sodium in their urine is summed up in Table 9. For the sake of comparison, the cumulative discomfort index for each of the participants for the entire duration of the test (40 hours) is also listed.

Average urine excretion per hour was 31 ml. The calculated sodium excretion for 24 hours averaged 2.35 g of sodium per subject (corresponding to 5.9 g table salt). Even though all men expended about the same effort, no correlation was found between the heat stress to which each of them was exposed and the excretion of urine or sodium in the urine.

4. Sodium Intake and Its Excretion Among Members of the Naturopath Village Amirim

Ten naturopaths from the naturopath village of Amirim near Safed, 9 of them men and one woman (who were assigned tests numbers 1-10), were under continuous observation during 8 days (including one Saturday) in August 1960. They ate and drank normally and in no way changed their mode of life. All of them had been naturopaths at least two years prior to the start of the test. Half of them were occupied in agricultural work, the other half did easier work or did no work at all. The climate during the test period (8.25.60-9.1.60) was relatively mild. Values for the cumulative discomfort index for the test days varied between 9.5-15.6.

The eating customs of the participants were not identical at all. Some ate food prepared with milk and bread and some even abstained from those.

The average intake of the subjects was 0.8 g sodium (corresponding to 2.0 g table salt) daily. Three persons had an intake of less than 0.25 g sodium, three were between 0.25-1.0 g sodium, while four (the bread eaters) used an average of 1.0-1.5 g sodium daily.

Sodium excretion in the urine was an average of 0.4 g daily (corresponding to 1 g of table salt). One subject excreted an average

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of more than 1 g of sodium daily, the others averaged less than 0.5 g of sodium in their urine during a 24-hr period (see Table 10).

It is worth pointing out that the amount of potassium in the food was very high and, therefore, also in the urine. The ratio of potassium/sodium in the urine averaged 33/11.

The average fluid intake per day was 2.4 liter. Daily average urine excretion was 0.9 l and average amount of perspiration given off was 1.6 l per person, daily (see Table 11). At least two of the subjects (2 and 9) were partially dehydrated all the time, which can be diagnosed from their low urine excretion - less than 0.5 l on the average.

If we assume that there were no unusual changes in the volume of the body fluids during the test period and that the quantity of sodium remains fixed under such conditions, what is left after excretion of sodium in the urine is lost through perspiration. Based on that assumption, the average sodium content of the perspiration was 0.2 g per liter.

From the clinical point of view, the 10 participants experienced no problems at all during the period of observation. On the last day of the test, the sodium level in the blood of all 10 naturopaths was checked. The sodium concentration was normal and equal to that of a control group examined at the same time.

Discussion:

The variations in the daily intake of sodium during the trip from Eilat to Metullah were relatively minor (see the last column in Table 1), despite the fact that four different menus were tried out along the trip which contained a varying percentage of canned foods. The menus during the trip were quite similar to those customary in the army, in kibbutzim, in large restaurants and, in fact, among the majority of the population It should be mentioned that, as an average, working people in Israel eat a regular diet that includes about 6 g of sodium per day or about 15 g table salt.

At the intake level of 6.08 g sodium daily (15.2 g table salt), the men excreted an average of 4.06 g of sodium (10.15 g table salt)

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Table 7

Urinary sodium excretion during a 24-hr period, in grams of sodium, for workers in Eilat. (These are average values for each of the 24 participants in the test.)

Subject Number	Number of Collections in 24 Hrs.	Average Sodium Excretion in Grams	Subject Number	Number of Collections in 24 Hrs.	Average Sodium Excretion in Grams
1	3	3.80	17	1	2.48
2	3	3.43	18	3	1.67
3	2	7.18	19	3	4.10
5	2	0.40	20	2	4.01
7	4	4.07	21	4	3.81
8	3	10.27	22	2	3.60
11	3	2.96	23	3	0.76
12	1	4.41	24	1	1.23
13	3	4.43	25	2	2.78
14	3	4.09	27	2	2.58
15	2	0.16	29	3	2.32
16	2	5.30	32	1	4.79

General average : 3.19 g sodium (corresponding to 8 g table salt)daily ,per person

Table 8

Comparison between Cum. D.I., urinary sodium excretion per hour (in grams) and urine excretion per hour (in ml) during periods of effort for 8 days of testing workers in Eilat.

Date	Cum. D.I. Effort	Sodium Excretion per Hr,in Grams	Urine Excretion per Hr.,in Ml
8-23	31.7	0.13	21
8-24	15.1	0.02	21
8-25	20.3	0.10	34
8-26	26.2	0.12	36
8-28	28.8	0.09	33
8-29	27.2	0.09	21
8-30	24.5	0.15	37
8-31	22.6	0.17	28
Average	24.6	0.12	33
Standard Deviation	-	0.087	18.6

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Table 9

Excretion of urine (in liters), urinary sodium excretion (in grams), and cumulative discomfort index for each of the participants of the ships' test.

Subject Number	Number of hours for which collected	Urine Excretion		Sodium Excretion		
		General	Per hr in ml	General	For 24 hrs.	
1	30	1.35	33	6.10	3.65	200
2	30	1.20	32	4.13	2.61	200
3	30	1.09	29	5.65	3.65	172
4	36	1.01	28	2.81	1.87	166
5	24	0.64	27	1.16	1.16	166
6	24	0.81	34	2.28	2.28	188
7	24	0.78	33	1.46	1.46	188
8	24	0.91	38	2.18	2.18	188
9	24	0.65	27	2.08	2.08	188
Average	—	—	31	—	2.29	—

Table 10

Average values for intake and excretion of sodium through urine (in grams for a 24-hr period) at the naturopath village Amirim.

Subject Number	Sodium Intake	Sodium Excretion
1	1.29	0.49
2	1.43	1.32
3	0.22	0.15
4	1.33	0.43
5	0.49	0.28
6	0.43	0.31
7	0.23	0.22
8	0.24	0.11
9	0.89	0.22
10	1.19	0.35
Average	0.8	0.4

daily. That alone shows that the regular diet included a large surplus of sodium and that there was no danger of any "negative sodium balance" starting. In other words: in spite of the sustained effort that caused the excretion of significant amounts of perspiration (5-10 liter daily), the sodium excretion through perspiration did not exceed the intake. In an indirect way it may be deduced that an

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Table 11

Average quantities of fluid intake, urinary excretion and sweat excretion (in ml for a 24-hr period) at the naturopath village

Subject Number	Fluid Intake	Urine Quantity	Sweat Excretion
1	3.69	0.87	2.87
2	1.46	0.48	1.06
3	2.76	1.10	1.71
4	2.49	0.84	1.69
5	1.36	0.79	0.52
6	3.35	1.82	1.76
7	2.35	0.97	1.66
8	2.59	0.95	1.74
9	1.57	0.44	1.18
10	3.19	0.72	2.84
Average	2.4	0.9	1.6

average of 2 g of sodium were excreted per day, so that the average sodium concentration in the perspiration was apparently 0.3 g per liter. These facts match the conclusions lately received from Malhotra and his coworkers [17, 18], with regard to sodium intake under conditions of effort and heat.

If we use the disappearance of sodium as an early sign of a developing salt deficiency, we will note that only once during the entire trip did one marcher excrete a zero amount of sodium in his urine; that was on 8.24.59 when the average for all men was the lowest. A partial explanation for the decrease on that day could be the fact that on that day the marchers came from a temperate zone into a hot zone, so that the amount of perspiration increased significantly (see Table 6) while the overall sodium intake on that day was below average (see Table 1).

There is an additional explanation - that the changes in the volume of the extracellular fluid are closely connected to the sodium balance. An increase in the volume of extracellular fluid "requires" sodium while a decrease in the volume of the fluid "releases" a certain amount of sodium. Bass et al. [4] found an increase in the volume of extracellular fluid with sodium retention during the first days, when the men were in a hot environment, with an increase in urinary sodium excretion for the following days.

In the same way, apparently, is the conspicuous rise in the average urinary excretion on 8.7.59 to be understood, side by side with the decrease in the cumulative discomfort index values (compare Tables 4 and 8).

The strong test of fluid intake limitation on 8.17.49 showed that regular sodium intake without concomitant fluid intake sets up a real danger for sodium increase in the bloodstream, as shown by Adolph et al. [2] and Tur et al. [29]. Actually, even when there is an unlimited supply of fluids, a person working in a hot environment is nearly always in a state of voluntary partial dehydration [2] and the addition of salt under such conditions could make it worse.

A further reason for abstinence from the addition of salt to the food is that such an addition apparently suppresses the excretion of aldosterone, which is considered today as one of the physiological systems whose job it is to preserve salt under conditions of conditions of effort and heat [15].

The tests carried out in the summer of 1960 exemplify three groups of people with different combinations of effort, heat stress and sodium intake: the workers in Eilat performed heavy physical work under very heavy heat stress conditions. The machinists in the engine rooms of the ship did not work hard but were under severe heat stress conditions. The two groups were fed a diet customary for the majority of the population. Average urinary sodium exretion of 3.19 g daily (Eilat) and 2.35 g daily (on the ship), shows that the salt quantity in a regular diet was more than sufficient for replacement of the losses caused by excretion of sodium in the preparation.

It should be pointed out that, because of the increase in the number of participants in Eilat, the possibility cannot be excluded that in one or the other case the collection of urine was not carried out correctly and that the values for urinary sodium excretion ought to be considered as minimum values for that reason. For instance, for three workers in Eilat who excreted average quantities of less than 1 mg of sodium in their urine during 24 hours, the record shows daily urine quantities of 0.5-0.6 liter. It is reasonable to assume

then that the collection of urine was not a complete one and that the excreted quantity of salt was larger than what we got in our calculation.

The naturopaths in Amirim did not work hard and enjoyed a relatively mild climate. Their sodium intake was extremely low - 1/7-1/8 of what is to be found in a regular diet Because of the low salt intake, the small amounts of sodium that were excreted cannot be considered as signs of salt deficiency. The naturopaths excreted an average of half the quantity of sodium that they absorbed in the food.

In the literature we find other examples of ethnic groups who, for socio-economic reasons are fed diets that are low in sodium. Dahl, in an article that surveys "The Intake and Need for Table Salt" [9], explains the low intake of no more than 1 g of sodium daily among members of the Kikuyu tribe in Africa [23] and among some of the population of China [21], who are mainly vegetarian. Among the meat eaters, the Eskimos [26] and the warriors of the Massai tribe in Africa [23] have a sodium intake of 1-2 g daily.

Conn's group proved [7, 8] that people can perspire up to 9 liter daily and retain a positive sodium balance at an input level of 0.75 g of sodium daily. The sodium concentration in the perspiration of those people dropped to below 0.1 g per liter.

Also described were people receiving treatment for high blood pressure by means of a low salt diet (100-200 mg of sodium daily) who maintain a positive sodium balance and have not clinical problems under conditions of effort and heat that parallel those found in our country in the summer [12], provided that there is no injury to their kidney functions and that they do not receive other types of medications.

The values of sodium in the bloodstream remained nearly constant during the trip and were normal among the naturopath group. Actually, no decrease of those values in the blood should be expected as the result of sodium deficiency, except in extreme cases where the distribution system of the kidney fails to function. It is known that in pathological cases no conclusions can be deduced about the

general quantity of sodium ions in the body from the quantity of sodium in the blood [31]. Hyponatremia is not necessarily evidence of a "negative sodium balance" but rather of a disturbance in the ratio of intercellular and extracellular water quantites [10, 22]. Similarly, pathological disturbances of the electrolytes do not stem directly from the sodium balance or from changes of its level in the blood but rather from changes in the osmolality of the body fluids [6].

From the clinical point of view, there were no phenomena in any of the groups that could be explained as signs of salt deficiency. The original description of the syndrome which is caused by salt deficiency, given by Talbot in 1933 [27] as characteristic muscle spasms (heat cramps) does not stand up under clinical and laboratory investigations from what is known today. Actually, the very existence of a pathological syndrome of salt deficiency, due to excessive perspiration, is in doubt and we found not a single case in the literature that would satisfy the criteria for a condition that could be diagnosed as "pure salt deficiency exhaustion," that is to say:

1) that a person would perspire a lot for an extended period and that, as a result of it and for that reason alone, he would develop characteristic symptoms of salt deficiency;

2) that a laboratory test would prove deficiency of salt alone;

3) that he would recover after receiving just salt.

In most of the cases that have been described, the picture presented of the illness is definitely non-specific and is composed of indications of heat stroke, shock as a consequence of dehydration and disturbances in the balance of the electrolytes (excess concentration). Laboratory tests make this mixed etiology quite transparent and recuperation is the result of treatment which, among other things, includes infusions of fluids with salt.

Given all that has been said above, it looks as if healthy people, who are acclimated and eat any kind of regular diet, are in no danger at all of sodium deficiency under conditions that prevail in our country in the middle of summer, either at places of

work, during hikes, or during army exercises. If any danger can be said to exist at all under conditions of effort and heat, it stems from the possibility of developing a great surplus of sodium when there is insufficient fluid intake. That situation could become more aggravated by having perspiring people take salt tablets, a bad habit under the conditions mentioned.

Summary

Intake and urinary excretion of sodium were investigated in a group of young, healthy and acclimated men during a trip from Eilat to Metullah in the month of August 1959 and in a group of naturopaths living near Safed in August 1960. Also investigated were the sodium excretions of workers in Eilat and of machinists in the engine rooms of a ship.

During the trip, the men consumed quantities of water, food and salt, according to their desires and the daily menu was generally much like the regular diet of the population. During the entire trip, there was not a single instance in which clinical or laboratory findings indicated salt deficiency, in spite of perspiration quantities of 5.5-10.3 liters daily.

The general sodium intake averaged daily about 6 g (corresponding to 15 g table salt), while the urinary excretion averaged about 4 g of sodium (corresponding to 10 g table salt). The balance was charged to the account of excretion through perspiration and changes in the volume of the body fluids. The sources of sodium were 82.9% on average from food, 12.4% from fluid intake and 4.7% from voluntary addition of salt. No direct functional relationship was found between sodium intake and the heat stress and perspiration quantities excreted.

The 35 workers who performed heavy physical labor under conditions prevailing in August in Eilat and who were fed regular diets, excreted an average of 3.19 g of sodium in their urine during a 24-hr period (about 8 g of salt).

The 9 machinists in the engine rooms of the ship during its departure, who were fed a regular diet as well and who performed light work under much more severe heat conditions, excreted an

average of 2.35 g of sodium (about 6 g of salt) daily.

The 10 naturopaths from the village of Amirim near Safed who worked very little in a relatively mild environment, had an average sodium intake of only 0.8 g daily because of their special eating habits and excreted an average of half that amount in their urine.

The combination of these four groups may be considered representative of nearly the entire population of Israel with regard to sodium balance under conditions of effort and heat. In none of these people did we see any clinical phenomena that could be explained as having been caused by a salt deficiency. It would seem there is no danger whatsoever of any salt deficiency in a population that eats a regular diet under summertime conditions in Israel. Under conditions of excessive perspiration and limited fluid intake, there exists the danger of a fast development of surplus sodium in the bloodstream. The addition of salt tablets to the food is superfluous and may even be harmful.

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